PROBLEM-BASED LEARNING AND COMPUTER-BASED SCAFFOLDS IN DISTANCE EDUCATION

Mahnaz Moallem[1] and Elizabeth Igoe[2]

[1]Ph.D. Towson University
Towson University, College of Education, Dept. of Educational Technology and Literacy
8000 York Rd. Towson, MD 21252-0001
[2]M.S.

ABSTRACT

What effects does PBL have on student learning outcomes, knowledge acquisition, and higher order thinking skills? This question continues to influence the adoption and implementation of problem-based learning (PBL) since its' inception. The answer to this overarching question is still lacking. This chapter responds to this question by first analyzing and synthesizing the literature regarding the factors that influence the effectiveness of PBL to identify questions that designers and researchers should ask about results of learning. It then explores important characteristics of PBL compared with its' analogous pedagogies and approaches of project-based learning, case-based reasoning, inquiry-based learning, learning design and/or design thinking in an effort to understand how features of each approach influence the effectiveness of learning outcomes. Further, the chapter examines how PBL approaches and pedagogies define learning outcomes and how various learning outcomes are measured. Finally, the chapter offers a synthesis of research on the effectiveness of PBL and recommendations for the future researchers and designers.

KEYWORDS

Problem-Based Learning, Effectiveness of PBL, PBL and Student Learning Outcomes, PBL Analogous Pedagogies, Comparison of PBL with its Analogous Pedagogies

1. INTRODUCTION

Problem-based learning (PBL) is an instructional approach rooted in constructivist and experiential learning theories. Research and theory on learning suggest that by having students learn through the experience of solving problems, they can learn both content and thinking strategies (Hmelo-Silver, 2004; Savery, 2006). In PBL, student learning centers around a complex problem that does not have a single correct answer or solution. Students learn content, strategies, and self-directed learning skills through collaboratively engaging in problem-solving, reflecting on their own experiences, and engaging in self-directed inquiry (Hmelo-Silver, Duncan, & Chinn, 2007). It has been maintained in the literature that PBL positively influences learning outcomes along with learners' higher order thinking skills such as creative thinking, problem-solving, logical thinking and decision making (Şendağ & Odabaşı, 2009). With the advent of reform movements in education, such as 21st Century Learning Skills, PBL is increasingly being advocated for and adopted by institutions of higher education.

However, while the utilization of PBL has expanded, disputes exist regarding the amount of scaffolding and guidance provided to students during implementation. Scaffolding is a temporary guidance provided to assist learners with the learning process. Kirschner, Sweller and Clark (2006) argue that PBL represents a minimally guided instructional practice. In contrast, Hmelo-Silver, Duncan and Chinn (2007) argue that PBL is not a minimally guided instructional approach, but "rather provides extensive scaffolding and guidance to facilitate student learning" (p. 99).

This dispute is relevant in higher education as the rate of online education programs continue to rise. PBL has traditionally been conducted in face-to-face settings using cooperative learning groups. Less is known regarding the successful implementation and facilitation of PBL online. Online education has emerged as a popular alternative to face-to-face classroom instruction. Most online courses are delivered asynchronously,

allowing instruction and communication between students and instructors to occur independent of time and location. However, the traditional implementation of PBL poses significant challenges to asynchronous online instructors in terms of scaffolding both individuals and groups.

The purposes of this study were to (1) design, develop and pilot test five self-directed, computer-based modules to support scaffolding in an online graduate level course utilizing Problem/Project-Based Learning (PBL), (2) collect data to assess the effectiveness of computer-supported scaffolding (hard scaffold) provided in the modules to assist students in problem identification, application of conceptual and domain-specific knowledge and skills of argumentation, and (3) use the results of the data to identify recommendations for future researchers and designers.

2. REVIEW OF THE LITERATURE

PBL is one of a family of constructivist, experiential learning approaches, which situate learning in a meaningful task (Hmelo-Silver, 2004), such as project-based learning (PrBL) and inquiry learning (IL) (Savery, 2006). Despite some differences among these approaches, the focus of each is a question, issue, case or problem that learners attempt to solve or resolve (Jonassen, 1999). In addition, problem-based approaches share the same assumptions about active, constructive and authentic learning experiences (Jonassen, 1999). Due to the similar characteristics, problem-based approaches such as PBL (Problem-based Learning), PjBL (Project-based Learning) and IL (Inquiry-based Learning) are often used in combination and play complementary roles in practice.

2.1 Process of Implementing PBL

PBL, as its name implies, situates learning in the context of a problem. The PBL learning cycle, also known as the PBL tutorial process, typically starts with the presentation of a problem rather than a lecture or reading assignment intended to impart discipline-specific knowledge to the student (Savery, 2009). The problem is ill-structured in nature and refers to an academically or professionally relevant issue (Yew & Schmidt, 2012) that students learn more about through the process of investigation and production of viable solutions. Students work in small collaborative groups to identify relevant facts from the provided problem scenario. As a group, students analyze the problem, generate possible explanations, as well as identify key issues and concepts they need to learn more about in order to solve the problem (Hmelo-Silver, 2004; Savery, 2009; Yew & Schmidt, 2012). After this period of teamwork, students disperse for a phase of self-directed study. Students independently research and investigate selected learning issues identified by the group. "They then regroup to share what they have learned, reconsider their hypotheses, and/or generate new ideas in light of their new learning" (Hmelo-Silver, 2004, p. 242). A tutor/facilitator is present during the group discussions to help facilitate the learning processes and the development of metacognitive skills (Savery, 2009; Yew & Schmidt, 2012).

PBL tutors/facilitators do not directly transmit/teach the content knowledge to students. Instead they support the students' learning process by observing the students, pushing them to think deeply by asking probing questions and encouraging students to articulate their thinking, modeling problem-solving strategies, and promoting collaboration among group members (Hmelo-Silver et al., 2007; Sockalingam, Rotgans, & Schmidt, 2011). It is noted in the literature that the role of the tutor or facilitator is critical to the successful implementation of PBL (Hmelo-Silver, 2004; Savery 2009). The tutor provides the initial guidance and supports with process skills, such as metacognitive modeling for individuals and groups, during collaborative group work (Savery, 2009). The tutor is responsible for both moving the students through the various stages of PBL and for monitoring the group process to assure that all students are actively involved (Barrows, 1988; Hmelo-Silver, 2004).

2.1.1 Role and Types of Scaffolding or Guidance in PBL

Scaffolding can be defined as support provided by a teacher, facilitator, tutor, peer, or a computer- or paper-based tool that allows students to meaningfully participate in and gain skill at a task that they would be unable to complete unaided (Belland, 2014). This concept of scaffolding has been connected to Vygotsky's zone of proximal development (ZPD), defined as the "distance between the child's actual developmental

level as determined by independent problem solving and the higher level of potential development as determined through problem solving under adult guidance and in collaboration with more capable peers" (Belland, 2014; Reiser, 2004; Vygotsky, 1978, p. 86). Enabling the learner to bridge this gap between the actual and the potential depends on the resources or the kinds of support provided (Puntambekar & Hübscher, 2005).

The original notion of scaffolding assumed that a single more knowledgeable person, such as a parent or a teacher, would help an individual learner, providing him or her with exactly the help he/she needed to move forward (Puntambekar & Hübscher, 2005). Strategies for scaffolding include (a) enlisting student interest, (b) controlling frustration, (c) providing feedback, (d) indicating important task/problem elements to consider, (e) modeling expert processes, and (f) questioning (Belland, 2014; Wood et al., 1976).

However, the reality of modern classrooms and the emergence of computer technologies has broadened the definition of scaffolding, expanding the potential sources of scaffolding and how scaffolds are delivered to students. Thus, scaffolds can be defined as tools, strategies or guides that support students in gaining higher levels of understanding that would otherwise be beyond their reach (Brush & Saye, 2002; Hannafin, Land, & Oliver, 1999; Simons & Ertmer, 2005). Scaffolds may assume multiple forms depending on the learning environment, the content, the instructor, and the learners (Simons & Ertmer, 2005). Brush and Saye (2002) conceptualize two categories of scaffolds: *soft* and *hard scaffolds* (Brush & Saye, 2002; Saye & Brush, 2002). *Soft scaffolds* are dynamic situational aid provided by a teacher or peer. Soft scaffolding requires teachers to continuously diagnose the understandings of learners and provide timely support based on student responses (Brush & Saye, 2002; Saye & Brush, 2002). This type of support is generally provided "just in time," where the teacher monitors the progress students are making while engaged in a learning activity and intervenes when support or guidance are needed. In contrast, *hard scaffolds* are static supports that can be anticipated and planned in advance based on typical student difficulties with a task (Brush & Saye, 2002; Saye & Brush, 2002). Such scaffolds can take the form of printed materials, such as worksheets, scripted cooperation and structured journals (Hmelo-Silver, 2004; Schmidt et al., 2011), or embedded within multimedia and hypermedia software to provide students with support while they are using the software (Brush & Saye, 2002).

3. COMPUTER-MEDIATED SCAFFOLDING: A DESIGN FRAMEWORK

Incombered by the review of the PBL literature, a conceptual framework was constructed to guide the design and development of problem-based, self-directed, computer-based modules to support scaffolding in an online graduate level course. As shown in Figure 1, the framework was designed to propose how the core characteristics of PBL can be used to create computer-based hard scaffolds to facilitate problem-based learning in the absence of an instructor or facilitator.
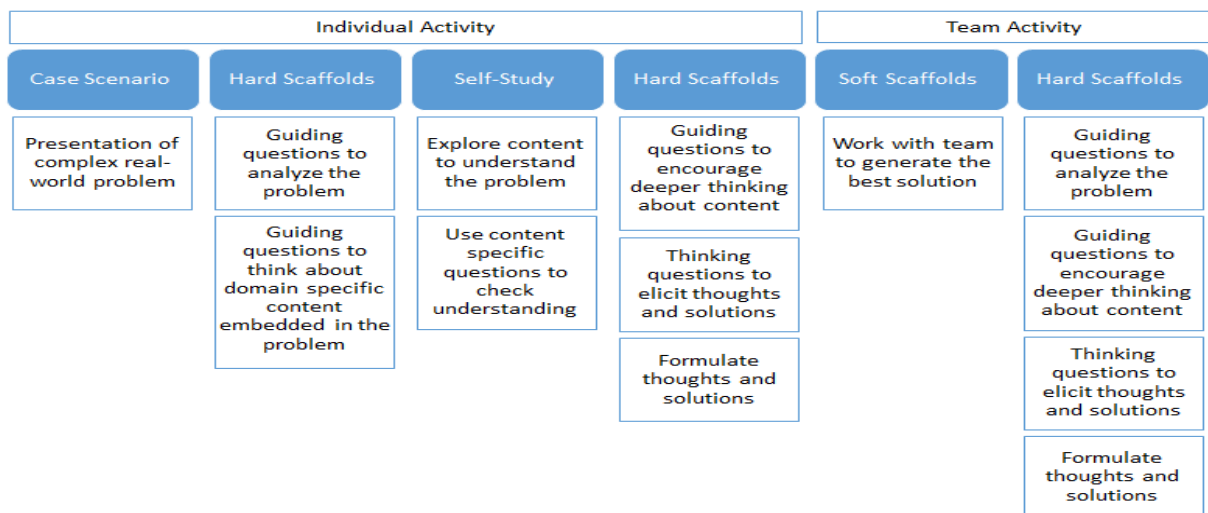

Figure 1. Design framework for online PBL modules

3.1 Top Hat: An Interactive Content Development Tool

A web-based PBL environment was specifically designed and developed for the purposes of this study. Top Hat was selected and used to develop the instructional materials. Top Hat is a commercially available, web-based teaching platform which offers two products marketed towards engaging higher education students in and outside of class: "*Lecture*," a classroom response system which allows for interactive slide presentations, and "*InteractiveText*," interactive learning materials to help students study. The latter product was used to develop the PBL modules for this study.

Interactive text, is a modern conceptualization of traditional textbooks. One of the unique elements of *InteractiveText* is the ability to embed questions within content. There is also a feature to allow students to respond with a drawing or graphical representation. Additionally, students can view each other's responses and engage in dialogue within the threaded discussion. These questioning functions allow an instructor to assess students' understanding in real-time or in advance of a class session. An instructor could use the data from assigned *InteractiveText* to identify issues and direct instruction towards areas where students are struggling.

3.2 Incorporating Scaffolds in Top Hat Modules

Using the Top Hat environment and the proposed framework, three online modules were developed. Each module focused on a targeted content embedded in an ill-defined problem statement. The students were to carefully read and analyze the problem statement to identify underlying concepts and issues, study them individually and then meet with their collaborative group to discuss and come up with the best solution. Thus, each module began with a real-world, ill-defined problem, which was used as the context for the instruction. In order to replace the human tutor who would normally guide learners' discussion when reviewing and analyzing the problem statement, a series of hard scaffolds in form of consecutive questioning were provided to assist students in problem identification and analysis while exploring and applying conceptual and domain-specific knowledge. Furthermore, the successive questioning as a hard scaffold was aimed to encourage deeper thinking, elaboration, and argumentation. The following explains two types of hard scaffolds that were used to assist the learners.

Analytical questions. Following the presentation of the problem, a series of "thinking questions" were provided to assist the learner in analyzing the problem. This line of questioning was designed to act as cognitive and metacognitive scaffolds by modeling the types of questions students should be asking of themselves. The thinking questions were related to both the domain-specific thinking, as well as self-regulation skills.

Domain-specific guiding prompts and questions. In addition to analytical questions, students were guided to review related readings and other multimedia materials to explore domain-specific knowledge. The resources provide real-world examples and explanations of theoretical concepts, model expert behavior/thinking, or demonstrate a concept in action.

4. THE METHODOLOGY

As indicated earlier, the Top Hat modules were designed to support and be incorporated into the activities of an existing online course. "Organization and Management of Instructional Technology" is an elective course offered to students in an instructional technology graduate program. Participants enrolled in this course are primarily graduate students seeking a master's degree or a certificate in instructional technology. The study was piloted during the fall semester 2016 and was conducted again in the spring semester of 2018. During fall 2016, the course met regularly once a week for three hours via WebEx while during spring 2018 no weekly virtual meeting was scheduled and the course was delivered asynchronously. In fall 2016, participants were both on campus (1) and at a distance (4) logging in for the class through the WebEx teleconferencing system. The researchers were present in the classroom during class sessions to observe live discussions and take notes.

The following questions guided the data collection process:

- To what extent do the Top Hat modules impact students' content knowledge acquisition and thinking skills?
- To what extent do the hard scaffolds in the Top Hat modules affect students' thinking and argumentation skills?
- What were students' perceptions of the Top Hat modules?

A design-based approach was used to systematically study the process of implementing and evaluating the learning materials. According to this iterative approach, the intervention could simultaneously be designed, developed, implemented and studied (Wang & Hannafin, 2005). During implementation, formative evaluation data was collected to systematically analyze the effectiveness of the modules and identify changes before implementing it again in spring 2018. This paper reports the results of 2016 pilot study. Both qualitative and quantitative data were collected and analyzed during fall 2016 to inform decisions. Data was collected from multiple sources including pre-posttests, student written responses to open-ended questions, student perception surveys and classroom observations.

Participants. A group of 5 students (3 female, 2 male) volunteered to participate in the evaluating the Top Hat intervention in fall 2016. None of the volunteers had previously participated in or completed the course. Additionally, three of five participants were completely new or novice to the process PBL.

5. RESULTS

Pre-posttest results for three modules were analyzed. Tests contained both close-ended questions (i.e., multiple choice and True/False) questions and open-ended questions which required short written responses. Close-ended questions were scored for correctness, while open-ended responses were scored using the rubric described above. In general, participants achieved an increase in their overall score from the pretest to the posttest. The average score among participants demonstrated growth in content knowledge and achievement for all three modules (Table 1).

Table 1. Summary of average pre-posttest growth

Test	Points Possible		Average Pretest Score		Average Posttest Score		Average Growth	
Module 2	22	100%	13	59%	16.5	75%	3.5	16.5%
Module 3	23	100%	14.6	63%	18.3	80%	3.7	16%
Module 4	19	100%	11.5	62%	13.75	72%	2	11%

While the results demonstrate that participants' scores improved from pre to posttest, each module pre-posttest included items which resulted in an average decline or minimal gain in scores among participants (Table 2).

Table 2. Summary of items with negative or minimal gain

Test	Item	Points Possible	Average Pretest Score		Average Posttest Score		Average Growth	
			#	%	#	%	#	%
Module 2	3	4	2.5	63%	2.75	69%	0.25	6%
	6	4	2.5	63%	2.25	56%	-0.25	-6%
Module 3	1	5	4.6	92%	4.2	84%	-0.40	-8%
Module 4	2	3	1.25	42%	2	67%	0.75	25%
	4	5	3	60%	3.25	65%	0.25	5%

Item 6 in the Module 2 experienced a 6% decline in average scores. The majority of participants' scores did not change between pre and post, while one participant's score declined. Additionally, Item 3 showed little gain (6%) compared to the other items. Each of these items asks participants to explain a concept and provide an example to support their answer. The lower scores reflect a difficulty providing reasoning and argumentation for more complex concepts within written responses. It is worth noting that Item 4 required participants to use the context of their course project in their response. While the item did achieve a small

gain (5%), it is telling that the module did not appear to improve their performance when applying the content to their project.

To assess the effects of hard scaffold on students' thinking and argumentation skills, written responses to open-ended assessment items within the Top Hat modules were scored and analyzed (see Table 3). The online activities for Modules 3 and 4 consisted of two parts; an individual activity followed by a team activity. The two parts were scored separately.

Table 3. Summary of Top Hat scores

Top Hat Module	Points Possible	Average Score	
		#	%
Module 2	47	28.1	65%
Module 3: Individual Activity	5	3.25	65%
Module 3: Team Activity	21	12.25	58%
Module 4: Individual Activity	8	4.67	58%
Module 4: Team Activity	15	7	47%

The average scores for open-ended responses were low (Table 4). However, it should be noted that among the five participants scores often varied widely per item. Scores appear to have been impacted by the weight placed on the level of argumentation and justification. Many open-ended questions consisted of both Level 1 and Level 2 components described in the scoring rubric (worth 4 points or more). The mediocre average scores reflect a general difficulty with the skills of argumentation and justification which made up the bulk of the possible points.

Participants generally lacked detailed reasoning or justification to support and explain their thinking. This could be because students are not used to defending their thoughts in writing, lack skills and knowledge regarding argumentation and reasoning, or that they felt rushed when completing the activity so they didn't take time to fully expand on their thoughts for each question. The low scores could also point to a lack in conceptual content knowledge or prior experiences which could have affected their ability to provide thoughtful and well-constructed arguments. Additionally, the low scores could indicate that the metacognitive and cognitive scaffolds did not support or provide enough guidance for students to fully achieve the learning task.

The results for team activities mirror the findings for individual activities. Scores were affected by the team's level of argumentation within responses. Both teams tended to provide superficial answers with very limited reasoning or justification within their responses. However, it should be noted that the question prompts in team activities focused on the application of domain-specific knowledge and the presentation of team generated solutions. The question prompts did not necessarily specifically request reasoning in writing, but practice in the domain would expect justification for solutions. Teams were observed discussing their answers and reasoning, but this collaboration was not reflected in the written responses. This could be due to the fact that one team member was acting as the scribe for the team and did not include all the conversation or thinking that led up to the compilation of the response. Or, it could be due to the format of the question prompts and embedded scaffolds. It is evident that the scaffolds did not provide enough guidance to teams to elicit the expected components of the written response.

The implementation of the Module 4: Team Activity consisted of the three participants enrolled in the course. As such, the team activity was designed to allow the team to use the context of the course project during the team activity. The opportunity to work within the context of their project did not appear to improve open-ended responses. However, the team was observed skipping past questioning scaffolds and moving straight from question prompt to question prompt. It can be assumed that the embedded questioning scaffolds did not attract attention within the modules or were perceived to be extraneous. The format of the question prompts directed much more attention as they required action from participants.

A survey was conducted to evaluate student perception of the Top Hat modules. The survey consisted of 23 items and each item was accompanied by a 5-point Likert scale, with 1 denoting the most disagreeable and 5 denoting the most agreeable. The survey questions were categorized under the dimensions of PBL approach, scaffolds, learning evaluation, and the web-based platform (Top Hat). The results of students' perceptions of Top Hat materials are shown in Tables 4-7.

Results indicate that participants generally agreed that the PBL approach was helpful and effective for interacting with and learning the content, as shown in Table 4. However, questions regarding skills associated

with PBL, items 4-10, such as collaboration and communication demonstrate a slightly wider range of responses, as illustrated by the standard deviation calculations. This is important to note because these skills are typically scaffolded by a facilitator in PBL during collaborative group sessions. During the Top Hat intervention, early group discussion on problem analysis was not facilitated by the instructor/tutor. The results demonstrate that the hard scaffolds were not sufficient to take the place of the presence of a facilitator, as scaffolds offered by an instructor or a trained tutor are provided on spot and in response to learners' thoughts (soft scaffold). Thus, it is likely that a human facilitator could better model thinking processes and promote skills of communication, collaboration and critical thinking, especially with students that are new or novice to the PBL approach. However, with such a small sample size it is difficult to generalize.

Table 4. Student perceptions of PBL approach

No	Statement	N	Mean	Std
1	The Top Hat modules helped me identify what I needed to learn more about.	5	3.8	0.84
2	The cases presented in the Top Hat modules were relevant.	5	4.4	0.89
3	I used prior knowledge and experiences to help me analyze the cases.	5	4.6	0.55
4	I had a chance to collaborate with other students.	5	4	1.73
5	Interacting with other students improved my learning.	5	4.2	1.10
6	I experienced quality interactions with the other students in terms of learning.	5	3.8	1.79
7	Learning by interacting with other students enhanced my confidence	5	3.8	1.79
8	The interactions with the other students enhanced my communication skills.	5	3.8	1.79
9	The interactions with the other students enhanced my collaboration skills.	5	3.8	1.79
10	Working with group members helped me make connections between ideas.	5	3.4	1.67

Students' perception of the Top Hat scaffolding questions indicate that participants perceived the recommended resources embedded in the Top Hat modules to be helpful and effective for interacting with and learning the content.

Table 5. Students' Perception of Top Hat Scaffolds

No	Statement	N	Mean	Std
1	The questions in Top Hat helped me identify critical issues in the cases.	5	3.4	1.67
2	The questions in the modules prompted me to think more deeply.	5	3.2	1.48
3	It was easier to learn with the guidance of questions incorporated in the Top Hat materials.	5	3.2	1.48
4	The videos, articles and other resources included in the Top Hat modules helped me make sense of the content.	5	4.4	0.89
5	The Top Hat materials provided guidance to the construction of new knowledge.	5	3.8	0.84

Table 6 shows how the participants evaluated the learning processes that they experienced. The results reveal that participants perceived the Top Hat product to be a helpful learning tool and the intervention to be effective.

Table 6. Students' evaluation of learning

No	Statement	N	Mean	Std
1	Top Hat materials helped in my learning of the content.	5	3.4	1.14
2	The Top Hat modules improved my understanding of the content.	5	3.8	1.10
3	I have gained new knowledge as a result of completing the Top Hat modules.	5	3.8	1.10
4	I feel better prepared to apply the content to my project after completing the Top Hat modules.	5	3.8	1.10
5	This type of activity is suitable for how I learn.	5	3.6	1.14

Table 7. Students' perceptions of Top Hat

No	Statement	N	Mean	Std
1	The Top Hat platform was easy to use.	5	4.4	0.89
2	I enjoyed the Top Hat modules.	5	3.8	1.10
3	I would use Top Hat again if given the opportunity.	5	4.4	0.89

6. DISCUSSION

In general, the results of the 2016 study are encouraging for the use of hard scaffolds to promote problem-solving in an online environment, where the presence of a tutor is less feasible compared to a synchronous (virtual) or face-to-face learning environment. It appeared that hard scaffolds provided an opportunity for students to question their knowledge and thinking, and encourage them to dig deeper into the content. Also, the Top Hat modules and the embedded hard scaffolds are perhaps more important for asynchronous online PBL courses where regulating one's learning process is more critical. Furthermore, while participants' reasoning skills did not seem to improve as a result of embedded hard scaffolds, their domain-specific knowledge seemed to show improvement, which indicates that participants gained conceptual knowledge. Additionally, participants seemed to find the learning materials engaging and helpful in learning the content and appeared to enjoy interacting with the course content through the Top Hat PBL modules. However, it is evident that the design and implementation of online modules could be used to modify the design of hard scaffolds embedded in the online PBL modules in spring of 2018.

REFERENCES

Barrows, H.S. (1988). *The tutorial process*. Springfield, IL: Southern Illinois University School of Medicine.

Belland, B.R. (2014). Scaffolding: Definition, current debates, and future directions. In J.M. Spector et al. (Eds.), *Handbook of research on educational communications and technology* (pp. 505-518). New York, NY: Springer Science+Business Media.

Brush, T. A., & Saye, J. W. (2002). A summary of research exploring hard and soft scaffolding for teachers and students using multimedia supported the learning environment. *The Journal of Interactive Online Learning*, *1*(2), 1-12.

Hannafin, M., Land, S., & Oliver, K. (1999). Open learning environments: Foundations, methods, and models. In C. Reigeluth (Ed.), *Instructional design theories and models* (Vol. II). Mahway, NJ: Erlbaum,

Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn? *Educational Psychology Review*, *16*(3), 235-266.

Hmelo-Silver, C. E., Duncan, R. G., & Chinn, C. A. (2007). Scaffolding and achievement in problem-based and inquiry learning: A response to Kirschner, Sweller, and Clark (2006). *Educational Psychologist*, *42*(2), 99-107.

Jonassen, D. H. (1999). Designing constructivist learning environments. In C. M. Reigeluth (Ed.), *Instructional design theories and models: A new paradigm of instructional theory* (Volume II, pp. 215-239). New York, NY: Routledge.

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist*, *41*(2), 75-86.

Puntambekar, S., & Hübscher, R. (2005). Tools for scaffolding students in a complex learning environment: What have we gained and what have we missed?. *Educational Psychologist*, *40*(1), 1-12.

Reiser, B. J. (2004). Scaffolding complex learning: The mechanisms of structuring and problematizing student work. *Journal of the Learning Sciences*, *13*(3), 273-304.

Savery, J. R. (2006). Overview of problem-based learning: Definitions and distinctions. *Interdisciplinary Journal of Problem-based Learning*, *1*(1), 9-20.

Saye, J. W. & Brush, T. (2002). Scaffolding critical reasoning about history and social issues in multimedia-supported learning environments. *Educational Technology Research and Development*, *50*(3), 77-96.

Schmidt, H. G., Rotgans, J. I. & Yew, E. (2011). The process of problem-based learning: What works and why. *Medical Education*. 45. 792-806.

Şendağ, S., & Odabaşı, H. F. (2009). Effects of an online problem-based learning course on content knowledge acquisition and critical thinking skills. *Computers & Education*, *53*(1), 132-141.

Simons, K. D., & Ertmer, P. A. (2005). Scaffolding disciplined inquiry in problem-based environments. *International Journal of Learning*, *12*(6), 297-305.

Sockalingam, N., Rotgans, J., & Schmidt, H. (2011). Student and tutor perceptions on attributes of effective problems in problem-based learning. *Higher Education, 62*(1), 1-16.

Vygotsky, L.S. (1978). Mind in society: *The development of higher psychological processes.* Cambridge, MA: Harvard University Press.

Wang, F., & Hannafin, M. J. (2005). Design-based research and technology-enhanced learning environments. *Educational technology research and development*, *53*(4), 5-23.

Wood, D., Bruner, J. S., & Ross, G. (1976). The role of tutoring in problem-solving. *Journal of child psychology and psychiatry*, *17*(2), 89-100.

Yew, E. H. J., Schmidt, H.G. (2012). What students learn in problem-based learning: a process analysis. *Instructional Science*, *40*(2), 371-395.